A CONTENT ANALYSIS OF REPRESENTATIVE PROCEDURAL ERRORS IN ASRS MAINTENANCE REPORTS

Kirsten Patankar, M.S.[1]; Diane Lattanzio, M.P.H.[2]; & Barbara G. Kanki, Ph.D.[3]
San Jose State University[1]; QSS Group, Inc.[2] ; NASA Ames Research Center[3]
Moffett Field, California

Procedural error is defined in this study as any information-related error involving documents (MEDA, 1994). We analyzed the narrative sections of 46 ASRS reports which represent procedural errors in maintenance. As a result of an exploratory analysis of these reports, two main groupings emerged: Document Deficiencies and User Errors. Within each group, four distinct scenarios (eight in total) characterized the reports. The most frequent scenario within the Document Deficiencies group was that information was missing while the most frequent scenario in the User Errors group was that users didn't read or follow the document. Additionally, the documents involved in the procedural errors were identified. The Maintenance Manual was the most frequently involved document in both groups.

Introduction

Over the last several years, the aviation community has recognized that maintenance error poses a serious threat to airline safety and profitability (International Civil Aviation Organisation, 1995). As many as 15% of major aircraft accidents have been attributable to maintenance error (Hobbs, 1999). Additionally, of the fourteen most recent major accidents investigated by the National Transportation Safety Board, seven involved maintenance deficiencies (NTSB, 2002). Maintenance errors also have a significant financial impact on airlines: for example, Marx (1998) suggests that maintenance error may cost up to one billion US dollars per year in the United States alone.

Procedural error is one type of maintenance error. Studies on procedures and documentation have looked at design of documentation (Patel, Prabhu, & Drury, 1992), how information is presented to mechanics (Prabhu & Drury, 1999), and various aspects of procedural error (Nord & Kanki, 1999).

In previous research, 44% to 73% of maintenance errors were identified as procedural errors (Veinott & Kanki, 1995; Nord & Kanki, 1999; and Patankar, Lattanzio, Kanki, & Munro, 2003). Additionally, in Nord and Kanki (1999) errors were fairly evenly distributed across documents, and three problematic aspects of the documents were discussed: inspection and verification issues (34%), [in]completeness of the documents (27%), and [in]correctness of the documents (22%).

However, studies of procedural error have been few, and the complexity of inter-related factors is just beginning to be understood. Therefore, this study took a descriptive/exploratory approach to answer the general question, 'What is the nature of procedural error in aviation maintenance?'

Method

In a previous study, we coded 1183 ASRS narratives using the Maintenance Error Decision Aid (MEDA). We grouped all procedurally related reports (458) together, and modeled that set of narratives using QUORUM (QUantitative, Objective, Representative, Unambiguous Modeler) to arrive at the top ranking 10% of reports—46. For a detailed explanation of this process, see Patankar, Lattanzio, Kanki, & Munro (2003). As noted in that document, we caution that ASRS reports are submitted voluntarily so they cannot be considered a measured random sample of the full population of like events (ASRS, 2002). Nevertheless, given the sample of reports collected, we can characterize the types of events and factors reported.

In this study, we explored the narrative sections of the top ranking 46 ASRS maintenance reports. For each report, we wanted to consider how the procedural errors could be characterized, and what documents were involved. Procedural error is defined in this study as any information-related error involving documents (MEDA, 1994). We reviewed the narratives in detail, asking two specific questions: 'What was the procedural error?' and 'What were the major documents involved in the procedural error?'

Results and Discussion

Document Deficiencies and User Errors. When we looked at the procedural errors in each report, two distinct groups emerged: reports that involved Document Deficiencies and those that involved User Errors. We defined Document Deficiencies as any procedural error in which the document was implicated by the narrator in the ASRS report. We defined User Errors as any procedural error in which the user of the document was implicated in the narrative of the ASRS report.

Scenario Types. Within the broad categories of Document Deficiencies and User Errors, a limited number of common Scenario Types were observed for each group. Within the Document Deficiencies group, four common Scenario Types summarized all 21 reports: 1) those in which information was missing from the document, 2) those in which information was incorrect, 3) those in which information was difficult to interpret, and 4) those in which information conflicted with another document or with the equipment.

Within the User Errors group, four Scenario Types summarized all 25 reports: 1) those in which a mechanic didn't read or follow the document, 2) those in which a mechanic lost the document, 3) those in which a mechanic made a Required Inspection Item (RII) error, and 4) those in which a mechanic made a Logbook error. The following table shows the two procedural error groups and their respective scenarios:

Table 1: Procedural Error Groups and Scenarios

PROCEDURAL ERROR GROUPS (46 reports)	
DOCUMENT DEFICIENCIES (21 reports)	USER ERRORS (25 reports)
Scen. 1-Missing Info	Scen. 5-Didn't read/follow doc
Scen. 2-Incorrect Info	Scen. 6-Lost document
Scen. 3-Difficult to Interpret	Scen. 7-RII error
Scen. 4-Conflicting Info	Scen. 8-Logbook Error

Documents Involved. Next, we asked the question, 'What were the major documents involved in the procedural error?' In order to answer this question, we looked for an explicit reference to a particular document in the narratives and determined the one document that was the most salient to that narrative. The most notable documents were as follows:

Maintenance Manual	Illustrated Parts Catalog (IPC)
Minimum Equipment List (MEL)	Airworthiness Release
Logbook	Structural Repair Manual (SRM)
Job Card	Attachment Card
Engineering Documents	Removed Parts Tag

By identifying Document Deficiencies and User Errors, their respective Scenario Types, and the documents involved in the procedural errors, we were able to make comparisons across scenarios within each group as well as comparisons between the Document Deficiency and User Errors groups. On the basis of these comparisons, we could better characterize the full set of 46 procedural errors.

In the following two sections, we present the findings for the two groups: first Document Deficiencies and second User Errors. We discuss the comparison of the two groups: across all eight Scenarios Types and across Documents Involved.

Document Deficiencies Group

Of the 46 ASRS reports used in this analysis, 21 (46%) reports emerged as procedural errors in which the document was implicated by the narrator in the ASRS report. There were four ways in which this commonly occurred: the document had information which was missing, incorrect, difficult to interpret, or conflicting. These four scenarios are described in more detail below.

Scenario One. In this scenario, information was missing from the document: tests, labels, procedures, or directives were missing. There were ten of 21 reports in this scenario, or nearly one half of the reports in the Document Deficiencies group.

The most frequently involved documents in this scenario were the Maintenance Manual and the MEL. In the following report, information about a three-part assembly was missing from the Maintenance Manual:

> To the best of my knowledge, I installed the new carbon seal assembly, left from the previous shift, per Maintenance Manual 72-61-06. …..later I found out that aircraft xyz did an unscheduled stop in wxz due to oil consumption on #4 eng. With some research, I realized that I had not installed the carbon seal assembly properly, but just 2 parts of a 3 piece assembly….the company Maintenance Manual 72-61-06 for carbon seal removal/installation does not cover the assembling of the 3 pieces into the complete assembly. The manufacturer's Maintenance Manual 72-61-06 does though…..I feel that the manufacturer's Maintenance Manual 72-61-06 should be incorporated into company Maintenance Manual 76-61-06. By doing so may prevent this from happening again.

Scenario Two. In this scenario, the document had incorrect information in it. Specifically, a procedure, part number or repair detail was incorrect. There were four of 21 reports in this scenario, or 19% of the reports in the Document Deficiencies group.

Four different documents were involved in this scenario: the Maintenance Manual, the IPC, the MEL, and the SRM. Noteworthy in this scenario was one case where there were five separate incidences of 'information incorrect in the document' and nothing had ever been done to correct it, according to the reporter. The mechanics eventually were given the assignment to correct the procedure.

> Aircraft arrived at gate with log write-up, with fault code 36-xx-yy. FIM manual said to change high pressure shut off valve. Lead mechanic called maintenance control and got MEL 36-xx- xy for system. MEL book has picture of location of valve at 1 o'clock position on right side of engine. The Maintenance Manual states in 36-xx-yy page 401 that valve is located high on right hand side of engine. There are 2 valves on right side of engine, one at 1 o'clock position and one at 3 o'clock position with same part number and are interchangeable. MEL states to lock HPSOV (high pressure shut off valve) in closed position, which Maintenance Manual said is high on right hand side which is the pressure regulator valve. We locked closed valve high on right side of engine… Pilot …..had no bleed pressure on right hand system and returned to field. I believe MEL book and Maintenance Manual are incorrect and …. need to be updated to show proper valve location on engine. Callback conversation with reporter revealed the following: the reporter stated that …..(there have been) at least five incidents….problem was discovered nine years ago and never corrected…mechanics have been given the assignment to correct the procedure with adequate pictures to preclude a repeat of this incident.

Scenario Three. In this scenario, the document was difficult to interpret. Specifically, this scenario consisted of reports in which narrators described documents as 'vague', imprecise', 'misleading' or 'unclear'. There were four of 21 reports in this scenario, comprising 19% of the reports in the Document Deficiencies group.

The MEL was the major document involved in three out of four reports in this scenario. For example, in this report, the mechanic says that the MEL is confusing:

> The fueler reported having trouble transferring fuel from center fuel tank. After talking with fueler and troubleshooting, I concluded that the center tank fuel quantity indication was malfunctioning. With the assistance of lead AMT, we deferred center tank fuel quantity per MEL. The MEL for deferring center tank fuel quantity is very confusing. Technician must research a total of 4 change order authorizations in the computer. If some have been accomplished, deferral is allowed. If some have not been accomplished, deferral is allowed. The lead AMT researched the change order authorizations and we both agreed that the change order auth had been accomplished because of the letter 'A' next to the change order auth number. I was wrong. The letter 'A' in that computer display is just a category of change order authorization and not an accomplished indicator….. Solution: company MEL should be precise in which change order auth display to use. Terminal AMT's rarely use these change order authorization displays. More training in this area and a less confusing MEL would prevent this from happening again.

Scenario Four. In this scenario, documents conflicted with one another and/or with the equipment. There were three of the 21 reports in this scenario, or 14% of the reports in the Document Deficiencies group.

The Maintenance Manual, MEL, IPC, and a Job Card were involved in this scenario. In the following extreme case, a conflict between a Maintenance Manual and a Job Card resulted in several installations, removals, and re-installations of the same part:

> Retrack actuator and walking beam was installed per Job Card xxx for gear change. Actuator and walking beam was removed per Maintenance Manual 32-32-11. Second shift installed retract actuator and walking beam per job card yyy step xx. As stated in Maintenance Manual, routine job card is to be used and not the Maintenance Manual. Anti-rotation bolt was found on work bench on second shift. Aircraft was checked and bolt was missing. Another rotation bolt is installed in step yy (z). Callback conversation with reporter revealed the following info: The reporter stated that anti-rotation bolt installation was not installed by the technicians because it was not called out in the Maintenance Manual proc. The reporter said he and another technician removed the gear retract actuator and walking beam using the job card which calls for removal of the anti -rotation bolt. The reporter stated the routine job cards are normally updated and revised continuously but the Maintenance Manual takes a longer period of time for Revision.

Comparison of Reports within Document Deficiencies Group

Within the four scenarios described, at least part of the problem lies with the documents themselves: they had information that was missing, incorrect, difficult to interpret or conflicting. With respect to documents involved, the Maintenance Manual was involved in all four scenarios and occurred in 48% of the 21 reports. It was the major document involved in Scenario 1 (missing information). The MEL was also involved in all four scenarios, occurred in 38% of the 21 reports, and was the major document in Scenario 3 (difficult to interpret). Errors with the IPC occurred only twice in this group (10% of the 21 reports), in Scenario 2 (incorrect information), and Scenario 4 (conflicting information). Errors with a Job Card, an Airworthiness Release, or a SRM occurred only once each (5% of the 21 reports). This suggests that when errors occur in documents, they are most likely to be in the Maintenance Manual or the MEL. This finding also suggests that if errors occur in the Maintenance Manual, they are more likely to be 'information missing' errors; and if they occur in the MEL, they are more likely to be 'difficult to interpret' errors.

User Errors Group

Of the 46 total ASRS reports, there were 25 reports (54%) of procedural errors in which the user of the document was implicated in the narrative of the ASRS report. There were four ways in which this commonly occurred: 1) a mechanic either did not read or follow the document, 2) s/he lost or didn't retrieve the document, 3) s/he made a Required Inspection Item error, or 4) s/he made a Logbook error.

Scenario Five. In this scenario, a mechanic reported that s/he did not read or follow a document. There were seven reports following this scenario, comprising 28% of the reports in the User Errors group.

The Maintenance Manual was the most frequently involved document in this scenario, found in five out of seven or 71% of the reports. For example, in the following report the mechanic did not read the Maintenance Manual:

> Original problem occurred on inbound flight xyz, outbound flight abc. Pushed back from gate in zzz, could not start #1 engine (no fuel flow). Flight canceled. Aircraft #jxz. Maintenance replaced fuel control, no help; part bad from stock. I replaced the second fuel control the morning of jun/xb/99. During replacement, noticed fuel line from fuel control to 2.5 bleed actuator was bent. ..I installed the line and aircraft made flight without incident. I later looked this up in Chapter 20 maintenance manual to find it was an illegal repair. Callback conversation with reporter revealed the following info: The reporter stated he did not leave the work area to check the maintenance manual procedures chapter 20 until the substitute hose was installed and the flight departed.

Scenario Six. In this scenario, a mechanic lost or didn't retrieve the paperwork from management. There were six reports in this scenario, comprising 24% of the reports in the User Errors group.

The documents involved in this scenario were: Engineering Documents, Airworthiness Release, Attachment Card, Removed Parts Tag, and Job Card. For example, the following report explains how an Attachment Card was lost:

> I inspected an installation of a right-hand main landing gear trunnion bearing and link….The mechanic signed off on the work and I stamped off on the inspection of the work on a routine work card, although the brake hydraulic lines were not connected. The connection of the lines was noted on a form attached to a non routine card being worked with the routine card. Later I found out that the form which the brake line work was noted on was lost. No documentation for the brake work existed after the loss of the paperwork. The result was the plane was released for service without the hydraulic brake lines connected for the right-hand main gear. They were later found and connected…..the company paperwork is archaic and will need to be updated…

Scenario Seven. In this scenario, a mechanic missed, overlooked, forgot, or made an unqualified sign-off of a Required Inspection Item (RII). There were six reports following this scenario, comprising 24% of the reports in the User Errors group.

The Maintenance Manual was the most frequently involved document in three out of six (50%) reports. For example, the following indicates how a mechanic overlooked an RII in a Maintenance Manual:

> … I replaced a number 7 slat actuator on aircraft xyz for precautionary due to an indication problem with previous history. I returned the aircraft to service but did not obtain a RII for the actuator replacement. For many years an RII was not required and it completely slipped my mind. If the Maintenance Manual was highlighted stating that an RII is required for the part being replaced, this may not be overlooked in the future.

Scenario Eight. In this scenario, a mechanic made a Logbook error. The mechanic used non-standardized language, signed off the Logbook incorrectly or incompletely, removed a page, or didn't consult an electronic Logbook. There were a total of six reports in this scenario, comprising 24% of the reports in the User Errors group. The following report shows how the mechanic neglected to make a Logbook sign-off:

> The autothrottles on aircraft xyz were on MEL. Another mechanic worked the autothrottle problem and did an operational check and cleared the autothrottle MEL. He signed the aircraft logbook off, that he did an operational check because he was not cat IIIa qualified on an md80. I was with him and observed this check which is the same check as a functional check. I then recertified the aircraft to cat IIIa status by clearing the MEL-34-00. I neglected to make a separate logbook sign-off, stating that an autothrottle functional check was completed, which I should have per maintenance manual procedures. I did not realize this until the aircraft had already left the station.

Comparison of Reports in the User Errors Group

Within the four scenarios described, the users of the documents didn't read or follow the documents (7/25 or 28% of the reports), or lost or didn't retrieve paperwork, made an RII error, or made a Logbook error in 6/25 or 24% of the reports each. The Maintenance Manual and the Logbook were the documents with which the mechanics most often had difficulty, in eight of the 25 reports or 32% and six of the 25 reports (24%) respectively. When mechanics made errors with the Maintenance Manual, it was most likely that they did not read or follow it. And when they made an error with the Logbook, it was most likely that they didn't use standardized language. Users also had difficulty with Engineering Documents in three out of 25 (12%) cases; these occurred most often in Scenario 6 (lost or didn't retrieve paperwork.) Users also made errors with the Job Cards in three out of 25 (12%) cases, and these occurred most often in Scenario 7 (RII errors). Users made errors with the MELs, IPC, Airworthiness Releases, Attachment Cards, and Removed Parts Tags much less frequently.

Comparison of Document Deficiencies and User Errors

Comparison of Scenario Types

Looking at all eight scenarios, Scenario 1 'Information missing on the document' was the major Document Deficiency (comprising 48% of Document Deficiencies), and Scenario 5 'mechanic did not read or follow the document' was the major User Error, comprising 28% of the User Errors. Despite the fact that the overall total of User Errors was slightly higher than Document Deficiencies (25 to 21), 'information missing in the document' (Document Deficiency) was the most frequently reported. Although our exploratory method of characterizing reports did not look for relationships between primary error types, these two common scenarios could easily be related; that is documents with missing information may be related to why mechanics fail to read or follow documents.

The remaining scenarios within the Document Deficiencies and User Errors groups were fairly evenly distributed, but all percentages of reports in the User Errors group somewhat exceeded those in the Document Deficiencies group. Table 2 illustrates the distribution of reports by scenario in the Document Deficiencies and User Errors groups.

Table 2. Percentages of Scenarios within Document Deficiencies and User Errors Groups

DOCUMENT DEFICIENCIES	%	USER ERRORS	%
Scen. 1 (10/21)	48	Scen. 5 (7/25)	28
Scen. 2 (4/21)	19	Scen. 6 (6/25)	24
Scen. 3 (4/21)	19	Scen. 7 (6/25)	24
Scen. 4 (3/21)	14	Scen. 8 (6/25)	24
TOTAL	100		100

Comparison of Documents Involved

Procedural errors involved ten major documents, but the Maintenance Manual was most frequently reported. While prevalent in both Document Deficiencies and User Errors groups, the number of reports involving the Maintenance Manual in the Document Deficiencies group was slightly higher (10/18) than that in the User Errors group (8/18) as shown in Figure 1. As mentioned earlier, however, there may be relationships between Document Deficiencies and User Errors that are not captured explicitly by this analysis.

The MEL was reportedly much more often involved in Document Deficiencies (8/9) than User Errors (1/9). This was due to the fact that three of the errors involving the MEL fell into Scenario 1 (information missing), and three fell into Scenario 3 (difficult to interpret). Thus, in spite of a relatively high reporting of Document Deficiencies with the MEL, there is not a correspondingly high reporting of User Errors involving the MEL. Unlike the case of the Maintenance Manual, we don't see many reports in which users fail to read or follow the MEL, or lose it.

While in smaller numbers, the opposite was true for Job Cards, where only one out of four of the reports occurred in the Document Deficiencies group, but three out of four occurred in the User Errors group. This indicates that it is more likely that users would have difficulty with Job Cards, than it is that the cards themselves would be problematic. Since the most common User Error is a read/didn't follow error, this indicates more of a process problem than a strictly task procedure problem.

The Logbook, a unique document that is filled in by mechanics, was by definition only found in the User Errors group.

The other documents reported were involved infrequently but showed some potential patterns. For example, Engineering Documents were involved in the User Errors group only and were found in Scenarios 6 (lost or didn't retrieve the document) and Scenario 7 (RII errors). This could suggest that procedural errors that involve Engineering Documents are tied less to the document itself, and tied more to how the user engages in the maintenance and inspection process. Interestingly, procedural error involving Engineering Documents seems to entail coordination across mechanic, engineering, and inspection groups. The IPC was shown to be a problematic (incorrect or conflicting) document itself, and was also tied to User Errors (did not read/follow). Airworthiness Releases, SRMs, Attachment Cards, and Removed Parts Tags were only reported once each, so little can be concluded about them.

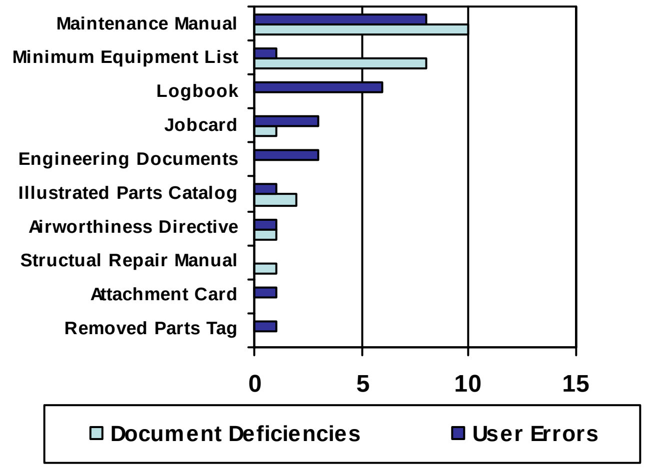

Figure 1. Frequency of Document Deficiencies reports vs. User Errors reports by Document Involved

Summary

Two distinct procedural error groups emerged from this study: Document Deficiencies and User Errors. Document Deficiencies comprised 46% of the reports in this sample, while User Errors comprised 54%. We further classified each of those groups into Scenario Types: four in each group. The most frequently occurring scenario in the Document Deficiencies group was that information was missing on the document. The most frequently occurring scenario in the User Errors group was that the mechanic did not read/follow the document. The document most often involved in both Document Deficiencies and User Errors groups was the Maintenance Manual. However, six other procedural error scenarios were identified within this sample and nine additional types of documents were involved.

In spite of the fact that ASRS reports cannot be used to predict statistical frequency of error events, they provide data rich enough to develop fairly detailed scenarios that describe the typical events reported. This level of detail can enhance our understanding of the common characteristics of different procedural errors, and, in turn, provide more specific guidance for developing error prevention strategies. As the ASRS maintenance database grows, we can refine our knowledge of procedural errors and further explore the relationships among error types and the contexts in which they occur.

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